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14. ABSTRACT
Access and retrieval of meteorological and oceanographic data from heterogeneous sources in a distributed system presents many issues. Effective bandwidth utilization is important for any distributed system. In addition, specific issues need to be addressed in order to assimilate spatio-temporal data from multiple sources. These issues include resolution of differences in datum, map-projection and time coordinate. Reduction in the complexity of data formats is a significant factor for fostering interoperability. Simplification of training is important to promote usage of the distributed system. Here, we describe particular techniques that revolutionize the Internet-based delivery of MetOc data to address the needs of the Warfighter.

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New Developments in Internet-Based Delivery of MetOc Data to Warfighters

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Abstract – Access and retrieval of meteorological and oceanographic data from heterogeneous sources in a distributed system presents many issues. Effective bandwidth utilization is important for any distributed system. In addition, specific issues need to be addressed in order to assimilate spatio-temporal data from multiple sources. These issues include resolution of differences in datum, map-projection and time coordinate. Reduction in the complexity of data formats is a significant factor for fostering interoperability. Simplification of training is important to promote usage of the distributed system. Here, we describe particular techniques that revolutionize the Internet-based delivery of MetOc data to address the needs of the Warfighter.

I. Introduction

Access to and retrieval of meteorological and oceanographic (MetOc) data from heterogeneous sources in a distributed system such as the Internet presents many issues. Among these issues, effective bandwidth utilization is important for any distributed system. Bandwidth utilization is of particular concern to the Afloat Warfighter. Assimilation of spatio-temporal data from Internet-based sources means that differences in datum, map-projection and time coordinate must be resolved. Reduction in the complexity of data formats is a significant factor for fostering interoperability. Simplification of training is important to promote usage of the distributed system. All of these concerns directly affect the Warfighter's ability to effectively access, collect and share data/information across the Internet.

The future requires military operations and intelligence communities to rely more heavily on automated Internet-based solutions for the delivery of MetOc data and products to the Warfighter. Many sources reference the growing need for this capability (e.g., the Department of Defense Net-Centric Data Management Strategy [1]).

These issues are being addressed by Tactical Environmental Data Services (TEDServices) [2]. TEDServices is being engineered by the Naval Research Laboratory (NRL), the Naval Oceanographic Office and the Naval Undersea Warfare Center, with sponsorship from

Space and Naval Warfare Systems Command (SPAWAR) PMW-155. The Naval Research Laboratory's Geospatial Information DataBase System (GIDB) serves as the prototype for TEDServices system components. The GIDB System has been under development and testing since 1994 under various sponsors with emphasis on Internet-based delivery of geospatial data from heterogeneous sources [3, 4].

II. GIDB Background

The Digital Mapping, Charting and Geodesy Analysis Program (DMAP) at the Naval Research Laboratory has been actively involved in the development of digital geospatial mapping and analysis systems. This work started with the Geospatial Information Database (GIDB™), an object-oriented, CORBA-compliant spatial database capable of storing multiple data types from multiple sources. Data is accessible over the Internet via a Java Applet [5].

The GIDB includes an object-oriented data model, an object-oriented database management system (OODBMS) and various analysis tools. While the model provides the design of classes and hierarchies, the OODBMS provides an effective means of control and management of objects on disk such as locking, transaction control, etc. The OODBMS in use is Ozone, an open-source database management system [6]. This has been beneficial in several aspects. Among these, access to the source code allows customization and there are no costly commercial database licensing fees on deployment. Spatial and temporal analysis tools include query interaction, multimedia support and map symbology support. Users can query the database by area-of-interest, time-of-interest, distance and attribute. For example, statistics and data plots can be generated to reflect wave height for a given span of time at an ocean sensor. Interfaces have been implemented to afford compatibility with Arc/Info, Oracle 8i, Matlab, and other applications/DBMS.

The object-oriented approach has been beneficial in dealing with complex spatial data, and it has also permitted integration of a variety of raster and vector data products in a common database. Some of the raster data include satellite

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and motion imagery, Compressed ARC Digitized Raster Graphics (CADRG), Controlled Image Base (CIB), jpeg and video. Vector data includes Vector Product Format (VPF) products from the National Imagery and Mapping Agency (NIMA), Shape, real-time and in-situ sensor data and Digital Terrain Elevation Data (DTED). The VPF data includes such NIMA products as Digital Nautical Chart (DNC), Vector Map (VMAP), Urban Vector Map (UVMAP), Digital Topographic Data Mission Specific Data Sets (DTOP MSDS), and Tactical Oceanographic Data (TOD).

Over the years, the system has been expanded to include a communications portal that enables users to obtain data

from a variety of data providers distributed over the Internet in addition to the GIDB. These providers include Fleet Numerical Meteorology and Oceanography Center (FNMOC), USGS, Digital Earth/NASA, the Geography Network/ESRI and others. The communications portal provides a convenient means for users to obtain MetOc data and incorporate it with other vector and raster data in map form. The GIDB communications portal establishes a well-defined interface that brings together such heterogeneous data and provides a common geo-referenced presentation to the user. An illustration of the interface for a typical data request is shown in Fig. 1.

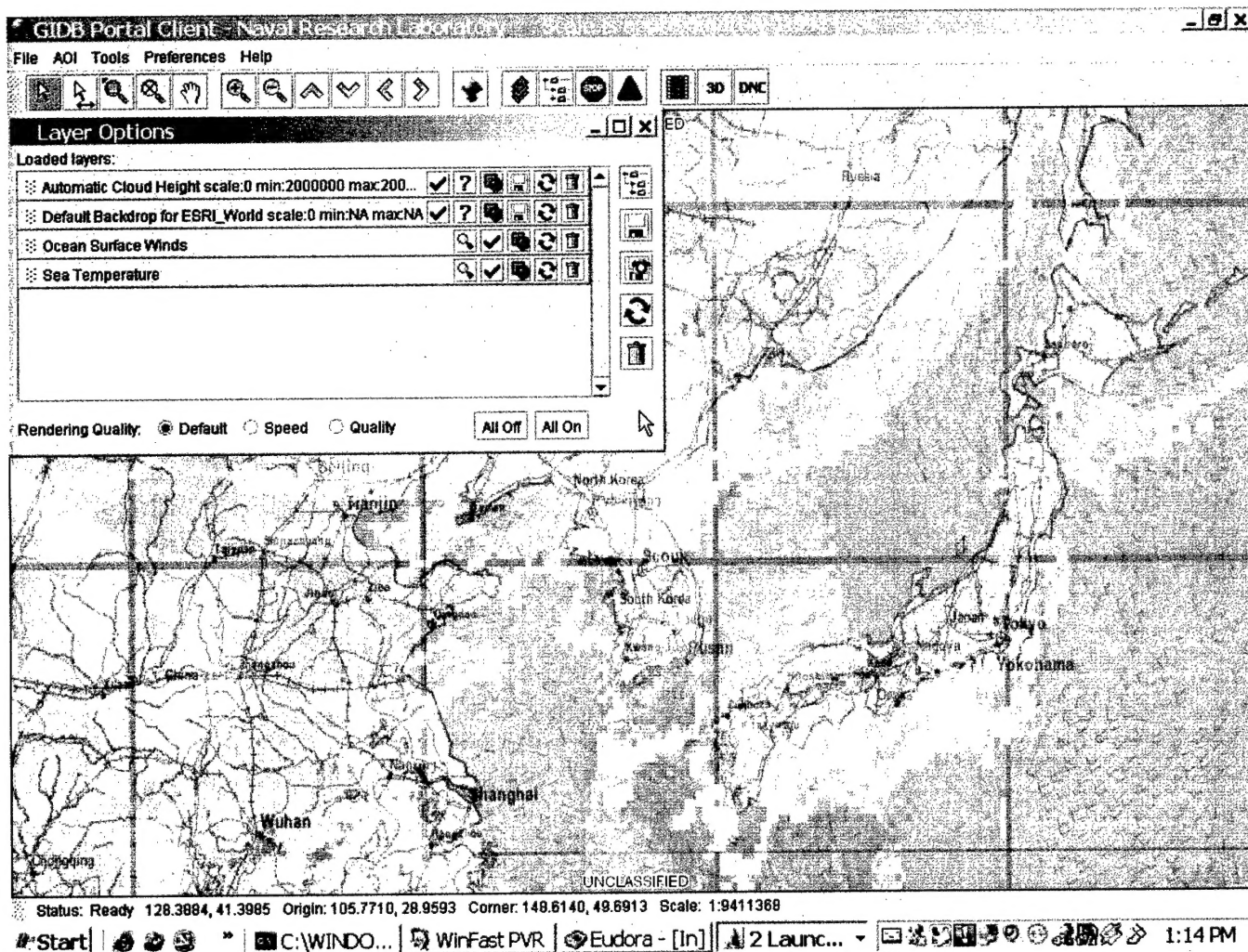


Fig. 1: GIDB Display of Internet Data Delivery

III. TEDServices

NRL's extensive work on GIDB was leveraged for the design and development of TEDServices. TEDServices is a new, scalable and modular environmental data delivery

system, designed to support Warfighters, Weapon Systems, and Expert MetOc Data Users.

It includes a middleware infrastructure that enables the interoperable transport and transform of data. This is accomplished in a manner consistent with WGS84 datum and

universal time coordinate, facilitated by a MetOc/Mission Rules Based Data Ordering scheme (MRBDO).

TEDServices provides a new Internet-based architecture within the Oceanographer of the Navy's (N096) Operational Concept 2002. Fig. 2 illustrates this Operational Concept.

Production Centers (e.g., FNMOC and the Naval Oceanographic Office (NAVO)) produce Numerical Weather & Ocean Prediction (NW&OP) data by assimilating global In-Situ Data.

Domain Authorities (DA) use NW&OP within an expert knowledge context, to derive the "MetOc Answer" and populate the Domain Authority Virtual Natural Environment (VNE). A Domain Authority can be co-located within a Production Center.

Centers of Expertise (CoE) will use data from the Domain Authority VNE to produce global CoE Products. A CoE can be co-located within a Production Center or Domain Authority.

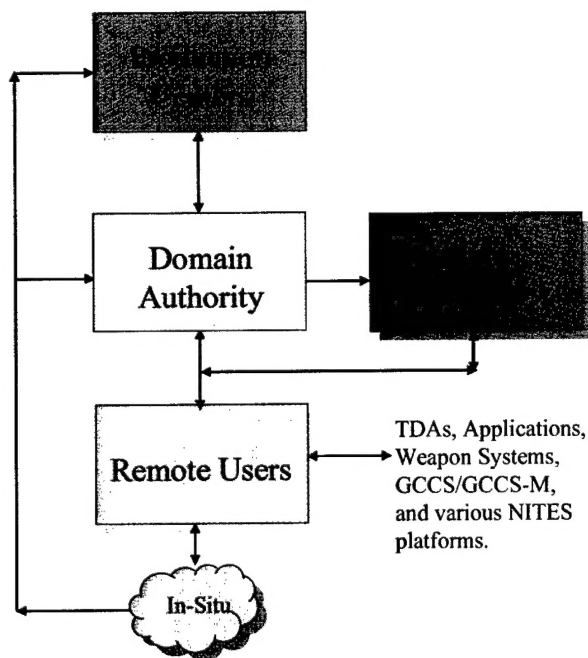


Fig. 2: N096 Operational Concept

A Remote User can be Ashore, Afloat or Mobile. A Remote User will use data/products from Domain Authorities and Centers of Expertise. A Remote User will also collect In-Situ data to be used by Production Centers and Domain Authorities.

Automated ingest and publish, together with data subscription capabilities provide the means for data delivery throughout the system.

The TEDServices design supports the automated management and bi-directional transport of meteorological, oceanographic and other environmental data/information. TEDServices offers a lightweight, forward deployed data cache, which provides Warfighters, MetOc professionals, Tactical Decision Aids (TDAs), Applications and Weapon Systems immediate access to the Virtual Natural Environment (VNE), a 4-dimensional representation of the User-defined battle-space environment. TEDServices' Clients will use a new MetOc/Mission Rules Based Data Order (MRBDO) process to subscribe to relevant data by mission, platform, TDA/application, parameter or product. The design tenants of TEDServices include: Data Transport (to reduce bi-directional bandwidth use), Data Management (to simplify data ordering and forwarded deployed data administration), Data Representation (implementation of a unified Geospatial and Time Coordinate Process), and DoD Joint Interoperability (supporting standards defined by the Joint MetOc Interoperability Board).

TEDServices offers a pure Java implementation for platform independence. It also provides planned support for the Joint MetOc Interoperability Board XML Interface Standard (Joint MetOc Broker Language – JMBL). A feature of TEDServices is the provision for remote administration of the system by authorized users.

IV. TEDServices Components

The conceptual components of TEDServices are shown in Fig. 3. These include GateWays, Local DataBrokers, Local DataStores, and Interface support. These components are explained below.

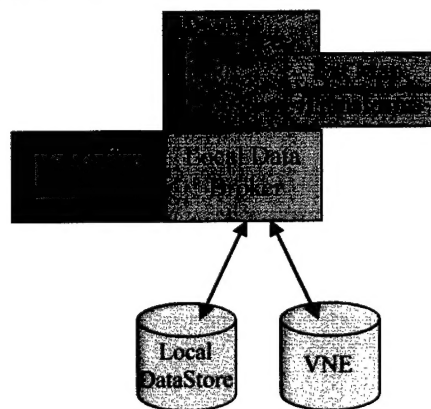


Fig. 3: TEDServices Conceptual Components

The Local Data Broker (LDB) embodies the "smarts" of the system to pre-stage needed data at a particular location. It "knows" how to contact other TEDServices GateWays to request needed MetOc parameters/products over particular areas of interest. The LDB also monitors data usage and cancels further delivery of data that is not being used. The LDB also works to mitigate redundant reach back requests

for the same data by multiple users. It does this by caching data so that the data is available to multiple users.

The GateWay component encapsulates the software that streamlines the process of integrating data from heterogeneous sources to a Common Transport Format (CTF). This CTF assures a uniform datum, uniform projection and universal time coordinate. A CTF for all data types within TEDServices simplifies format transformations to end-users and is a significant factor for fostering interoperability. A MetOc/Mission Rules Based Data Ordering (MRBDO) system allows data requests to be aligned with relevant mission specific packages and platforms. This reduces the likelihood of requests for data that are not essential to a particular task. It also offers a means of simplifying training.

The Interface component is responsible for a number of tasks, including:

- Receiving user requests for data and products.
- Handling user requests to obtain data in a number of supported file formats (e.g., netCDF, draw for FalconView, ShapeFile, MIFF, etc.).
- Interpolating gridded data to a user-specified spatial resolution.
- Establishing an order (subscription) for data to be forward-deployed at the platform or location.

The Local DataStore/VNE provides a forward-deployed object-oriented cache for data and products, which are accessible via the Interface. This cache uses the Java Ozone OODBMS and allows for remote administration.

Together, the TEDServices components form a TEDServices GateWay. There is ideally one TEDServices GateWay per platform or location. This TEDServices GateWay serves all users and applications at that platform or location. This obviates the need for multiple reach backs for the same data by multiple users. Obviating this type of reach back serves to reduce bandwidth usage. TEDServices GateWays communicate with each other to forward deploy needed data to the end-user. User applications access data only from their local TEDServices GateWay.

V. Large Scale Data Transfer

Large scale data transfer can be difficult when network communications are unstable. TEDServices employs Resumable Object Streams (ROS) for all data traffic between major components of TEDServices across the network to achieve fail-safe data transportation under these conditions. ROS allows either the client or server side of a request to lose network connection, regain it, and the request will continue where it left off. In the event of a server shutdown and restart, server side processing of requests does not require the client to resend the request. Retransmission of the previously transmitted portion is not necessary in either case. Data requests can still be wrapped in compression and/or

encryption. The ROS transmission controls add almost no storage overhead to the communication (approximately 13 bytes).

A dynamic packet compression scheme (LPAC) was developed in conjunction with GMA Industries, Inc. under a Small Business Innovation Research (SBIR) Phase II program, under the direction of the MetOc Systems Program Office at SPAWAR. LPAC provides higher lossless compression ratios than data compression methods currently favored by MetOc data users for large gridded data sets. Data is compressed prior to network transmission. It is also stored in the compressed format and uncompressed only on extraction to end-users. A Java-implementation of a DataBlade-like data extraction tool was transitioned to TEDServices by Barrodale Computing Services (BCS), under the direction of the MetOc Systems Program Office to provide the methods for complex extractions from these datasets.

VI. Collaborative Application Sharing

A Collaborative Application Sharing Process (CASP) is implemented in TEDServices to enable remote application users to share the state of their applications as well as to share information across the Internet. This means that some of the mission planning requirements can be placed at "Centers of Expertise" where experts can perform some of the less time-critical planning and provide results to the field. This allows, in a U.S. Navy setting, heightened situational awareness in a distributed environment.

When CASP is used to share an application's state, users send to TEDServices a Java object that encapsulates the state of their application. This state is stored within TEDServices in a non-application specific manner. When the object is retrieved from TEDServices, the remote user may open the CASP object. This will restore the application's state to the state contained within the CASP object. The user may then make any appropriate modifications and re-submit the object back to TEDServices for further dissemination and sharing.

CASP can also be used to publish information such as Ordnance Employment Fields (OEF). Operational units can use CASP to share information rather than the data that was used to create the information.

The model for CASP is a publish and subscribe paradigm. A typical CASP scenario follows. One or more parties subscribe to a particular CASP product from a remote TEDServices GateWay. When the CASP product is published to that GateWay, the GateWay automatically pushes the product to all subscribing parties. All subsequent updates to the CASP product are automatically pushed to the subscribing parties as well. Subscribing parties that received the CASP product modify the CASP product based on local knowledge. Then, they re-publish the updated CASP object back to TEDServices for further dissemination and sharing.

Applications currently integrated with CASP include the Naval Integrated Tactical Environmental Subsystem II (NITES II) Object Oriented Redesign (OOR) and the Joint MetOc Viewer (JMV).

VII. FBE-K

In April 2003, TEDServices was demonstrated in Fleet Battle Experiment – Kilo (FBE-K). TEDServices GateWays were installed at the following locations: the Carl Vinson, NRL Monterey (FNMOC), the Naval Oceanographic Office (NAVO), NPMOC-Yokosuka, NPMOC-Pearl, the Naval Undersea Warfare Center (NUWC), the Fleet MetOc Advance Concepts Lab (FMACL), Guam and NRL Stennis Space Center. Atmospheric data was transferred from FNMOC to the TEDServices GateWay at NRL Monterey where it was automatically ingested into TEDServices. Similarly, oceanographic data was transferred within NAVO to the TEDServices GateWay there, where it was ingested into the TEDServices VNE. All TEDServices GateWay to GateWay communications occurred on the SIPRNET.

NPMOC-Pearl subscribed to parameters being published at the NAVO TEDServices GateWay. Upon receipt of these parameters, NPMOC-Pearl used them as first guess fields to run the Modular Ocean Data Assimilation System (MODAS). The value-added data was then published at the NPMOC-Pearl GateWay and was then pushed to other TEDServices GateWays (Carl Vinson, Fleet Mac Lab, GUAM and NUWC) based on their data subscriptions for particular parameters and areas of interest.

Remote Users used the NITES II OOR TDA to utilize the data that was received on the local TEDServices GateWays. In addition, data was obtained from the FMACL TEDServices GateWay by another TDA (PC-IMAT) via the TEDServices Data Ordering Client. The latter is a Java-based GUI providing support to legacy systems. Remote Users in the Modeling and Simulation community (OASES) obtained data from TEDServices via the TEDServices Data Ordering Browser. JMV and NITES II OOR utilized the CASP publish and subscribe system to share application state and information/products.

A post-FBE-K "Hot Wash" was conducted at which evaluations and feedback were gathered from TEDServices users. Overall, the results indicate TEDServices does provide a revolutionary system for providing data to the Warfighter.

VIII. Summary

We have discussed issues pertinent to the Internet-based delivery of MetOc data for network centric warfare. We have shown how TEDServices employs a number of advanced techniques for improved management and better Internet-based delivery of MetOc data to the Warfighter.

We have covered means for improving bandwidth usage and methods to resolve differences in datum, map-projection and time coordinate. Techniques for the reduction in the complexity of data formats were presented. System aspects that use a rule base to simplify training and also reduce bandwidth utilization were explained. We have also shown how TEDServices uses automated data ingest along with a publish and subscribe paradigm to reduce end-user interaction for acquiring data. Methods for handling large scale data transfer and collaborative application sharing were also discussed. Finally, we have shown how TEDServices was demonstrated on the SIPRNET in Fleet Battle Experiment – Kilo.

IX. Acknowledgments

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